Studies in Rural Finance

Economics and Sociology
Occasional Paper No. 1089

Intermediation Costs in an Agricultural Development Bank: A Cost-Function Approach to the Measurement of Scale Economies

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February, 1984

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Abstract

This paper utilizes a translog model to investigate the cost-output relationships prevailing in the Agricultural Development Bank of Honduras. Overall scale economies are close to one, though they are a function of output levels. There are important scale economies in mobilizing deposits. Cost complementarities between loans and deposits exist.

*I wish to thank Professors Douglas Graham, Francis Walker, and Dale Adams for their helpful suggestions and encouragement. Responsibility for the final product remains all mine.

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1. Introduction

Knowledge of the characteristics of the production technology of financial institutions is essential for the analysis of market structure and institutional performance. Many regulatory and managerial decisions are based on specific assumptions about economies of scale and other features of the cost-output relationships prevailing in these institutions. Consequently, in recent years several studies have been concerned with the measurement of scale economies and cost complementarities in the production of financial services.[1/] However, very few attempts have been made to analyze these cost-output relationships in development banks operating in less-developed countries. In these countries, a substantial degree of regulation usually prevails thus making the knowledge of the production structure of financial institutions even more important, in order to assess the likely consequences of regulatory decisions.

Studies on development banks in less-developed countries by Gheen, and Nyanin, have provided very limited insights into the characteristics of the cost structure and underlying technology of these institutions, due to the choice of very restrictive functional forms for the cost function. In general, the use of Cobb-Douglas or CES specifications implies the adoption of highly restrictive assumptions about the technology utilized by financial intermediaries. Under these specifications, scale economies are forced to remain constant, regardless of the level of output, therefore the corresponding average cost curves are either downward or upward sloping throughout the entire output domain.

In this paper, a translog cost function is utilized to analyze the cost-output relationships and production technology of the Agricultural Development Bank of Honduras. Emphasis is placed on the measurement of scale economies, and on the sensitivity of this measure to the choice of functional form and estimation procedure. This cost function approach also allows the assessment of cost complementarities (economies of scope) in the provision of banking services. In addition, estimates of the elasticity of factor substitution and the price-elasticities of factor demands are obtained based on the estimated parameters of the translog cost function.[2/]

The following section presents the model utilized in this paper and its main properties. Data and estimation procedures are discussed in Section 3, and the results of different estimation techniques are presented in Section 4. The final section summarizes the main findings of the study.

2. A Translog Cost Function

Cost minimization subject to a production constraint yields a cost function that depends on output levels and factor prices. The translog cost function is essentially a second-order approximation to an arbitrary cost function. For two outputs and two inputs, the translog function is written as follows:

$$\begin{aligned} \ln C = {} & \alpha_0 + \alpha_1 \ln q_1 + \alpha_2 \ln q_2 + \beta_1 \ln p_1 + \beta_2 \ln p_2 + \frac{1}{2}\gamma_{11}(\ln q_1)^2 + \\ & + \frac{1}{2}\gamma_{22}(\ln q_2)^2 + \gamma_{12}\ln q_1 \ln q_2 + \frac{1}{2}\delta_{11}(\ln p_1)^2 + \frac{1}{2}\delta_{22}(\ln p_2)^2 + \\ & + \delta_{12}\ln p_1 \ln p_2 + \eta_{11}\ln p_1 \ln p_1 + \eta_{12}\ln q_1 \ln p_2 + \eta_{21}\ln q_2 \ln p_1 + \\ & + \eta_{22}\ln q_2 \ln p_2. \end{aligned} \tag{1}$$

where, q_i = quantity of ith output

q_1 : loans, q_2 : deposits

p_j : price of jth input

p_1 : salaries and wages, p_2 : price of capital services.

The cost-share equations for the two factor inputs derive from equation (1) as:

$$S_j = \beta_j + \Sigma_h \delta_{jh} \ln p_h + \Sigma_i \eta_{ij} \ln q_i, \quad j,h = 1,2, \quad i = 1,2, \tag{2}$$

where S_j denotes the cost share of factor j,

Cost function (1) should be homogenous of degree one in input prices. This condition imposes a set of restrictions on the parameters of equation (1) that is also consistent with the requirement that the sum of the cost shares (2) must equal one:

$$\Sigma_j \beta_j = 1, \quad \Sigma_j \delta_{jh} = 0, \quad \Sigma \eta_{ij} = 0, \quad j,h = 1,2, \quad i = 1,2.$$

Several properties of the cost structure and the underlying production function can be investigated using the translog cost function defined in equation (1). These properties are summarized below.

Economies of Scale

Overall economies of scale, ES, are defined as the percentage change in cost when all outputs increase by a common factor, λ. In equation (2), scale economies are measured as:

$$ES = \frac{\partial \ln C}{\partial \ln q_1} + \frac{\partial \ln C}{\partial \ln q_2},$$

$$\text{i.e., } ES = \alpha_1 + \alpha_2 + \gamma_{11} \ln q_1 + \gamma_{22} \ln q_2 + \gamma_{12} (\ln q_1 + \ln q_2) + (\eta_{11} + \eta_{21}) \ln p_1 + (\eta_{12} + \eta_{22}) \ln p_2. \tag{3}$$

Note that scale economies are a function of the output levels, q_1 and q_2, therefore the ES measure is not invariant to scale and is dependent on the output mix. If ES is less than 1, there are economies of scale since costs increase proportionately less than output. Values of ES equal to or greater than 1 imply constant returns or diseconomies of scale respectively. Partial economies of scale, ES_i, and marginal costs of each output, MC_i, can be computed from equation (1) as:

$$ES_i = \frac{\partial \ln C}{\partial \ln q_i}\ , \text{ and } \qquad MC_i = \frac{C}{q_i} ES_i = \frac{C}{q_i} \left(\frac{\partial \ln C}{\partial \ln q_i}\right) . \tag{4}$$

<u>Cost Complementarities (Economies of Scope)</u>

Cost complementarities exist in multi-output production when the marginal cost of producing one output declines with increases in production of another output.[3/] In terms of the parameters of the cost function (1) a necessary condition for the existence of cost complementarity between loans and deposits is:

$$\gamma_{12} + \alpha_1\alpha_2 < 0 \tag{5}$$

<u>Elasticity of Substitution and Elasticities of Input Demand</u>

Uzawa has shown that the Allen partial elasticity of substitution between factors of production, σ_{jh}, can be written in terms of the (dual) cost function as:

$$\sigma_{jh} = \left(\frac{\partial^2 \ln C}{\partial p_j \partial p_k} \Big/ \frac{\partial \ln C}{\partial p_j} \frac{\partial \ln C}{\partial p_h} \right) + 1 . \tag{6}$$

In terms of the parameters of the translog cost function (1) and the factor shares (S_j), the Allen partial elasticities of substitution can be computed as:

$$\sigma_{jh} = (\delta_{jh} + S_j S_h)/S_j S_h\ , \ \sigma_{jj} = (\delta_{jj} + S_j(S_j - 1))/S_j^2,$$
$$j,h = 1,2 . \tag{7}$$

In addition, the price elasticities of demand for inputs, e_{jh}, can be obtained using the estimated values of σ_{ij} and the factor shares (see Binswanger).

$$e_{jj} = \sigma_{jj}S_j \ , \quad e_{jh} = \sigma_{jh}S_h \ , \quad j,h = 1,2 \ . \tag{8}$$

It is clear from (7) that if all $\delta_{jh} = 0$, then the elasticities of substitution are independent of factor prices, and equal to one for $j \neq h$. Furthermore, if all $\gamma_{ik} = 0$, $\delta_{jh} = 0$, and $\eta_{ij} = 0$, the cost function (2) reduces to a Cobb-Douglas-type cost function:

$$\ln C = \alpha_0 + \alpha_1 \ln q_1 + \alpha_2 \ln q_2 + \beta_1 \ln p_1 + \beta_2 \ln p_2 \ , \tag{9}$$

with scale economies equal to $(\alpha_1 + \alpha_2)$ and unitary elasticity of substitution.

3. Data and Estimation

Data utilized in this study correspond to 28 branches of the Agricultural Development Bank of Honduras, over the 12-year period 1971 through 1982. All variables have been expressed in real terms (lempiras of 1966)[4/] using the country's implicit GDP deflator. These variables are briefly defined below.

(a) Costs. Total non-financial operating expenses, net of depreciation and provisions for bad debt.

(b) Outputs. Total value of loans (q_1), and total amount of deposit balances (q_2). Preliminary regressions on the data showed that this definition of outputs provided consistently better fits than any of the alternative definitions (number of loans and deposit accounts, or aggregate output).

(c) Factor Prices. Two factors are considered here: labor, and capital goods. The price of labor services (p_1) is measured as total personnel costs including benefits and social security payments divided by the total number of employees. A unit price of capital services (p_2) is proxied by the ratio of depreciation plus rents paid over the total value of loans plus deposit balances.

(d) Loan Size (LS) and Deposit Size (DS). These variables are included in the model to account for the heterogeneity of loans and deposit transactions. They are included in the cost function in interactive form with the output levels:

$$\theta_1 \ln q_1 \ln LS + \theta_2 \ln q_2 \ln DS.$$

In this way, both the scale-economies indicator and the marginal costs of production become dependent on the average size of loans and deposits.

Estimation of the translog cost function (1) is undertaken both as a single equation (by OLS), and as a cost system with the cost-share equations (2). Since cost shares must add to 1, one of these equations is redundant and therefore is dropped from the system. The remaining equations in the system, the cost function and the labor-share equation, are seemingly unrelated and the estimation of this two-equation system utilizes a generalized least squares procedure. As will be shown later, aside from efficiency gains there may be important differences in the magnitude of the estimated parameters resulting from different estimation procedures. As a consequence, the scale economies measure (and other parameters) will differ depending on the estimation technique.

4. Results

Functional Form and Scale-Economies Estimates

The Cobb-Douglas functional form (9) generated scale-economies measures that underestimate the cost increasing effects of output expansion, as compared to the estimates obtained with the translog functional form. The translog form resulted in a significantly better fit over the Cobb-Douglas form, according to the F-ratios obtained when testing for equality of the two regressions. Furthermore, tests conducted on the parameters of the (unrestricted) system of equations formed by the cost function and the labor share equation rejected the hypothesis of a simplified (Cobb-Douglas-type) functional form (9) with unitary elasticity of substitution.[5/] Loan size and deposit size interactions were not statistically significant in the single equation estimation, however, the addition of these variables affected the estimated magnitude of economies of scale in the translog specification.

Single Equation and System Estimation

A detailed comparison of the results obtained with single equation (OLS) and system estimation (GLS) procedures is presented in the appendix table. System estimation improves the overall goodness of fit and specially the statistical significance of individual coefficients. More importantly, scale-economies measures obtained with the cost-system estimation differ significantly from those resulting from the corresponding single-equation estimations. Table 1 shows the partial and overall economies of scale obtained using the system estimation procedure. In this case, the overall ES value is not significantly different from one. It is important to note however, that the values reported in Table 2 are not independent of scale effects and output mix. To analyze this result it is useful to recall equation (3):

$$ES = A + \gamma_{11} \ln q_1 + \gamma_{22} \ln q_2 + \gamma_{12} (\ln q_1 + \ln q_2) \,, \qquad (3')$$

where, A summarizes all parameters and variables in equation (3) that do not involve output quantities.

Scale economies tend to disappear (ES approaches 1) as output increases, since both $\hat{\gamma}_{11}$ and $\hat{\gamma}_{22}$ are positive. There is however an offsetting effect due to joint production of q_1 and q_2, since $\hat{\gamma}_{12} < 0$. The overall

Table 1. Economies of Scale Estimates, at Different Branch Sizes. Cost System Estimation 1/

	Sample Mean	"Small" Branch Case	"Large" Branch Case
Partial ES ($\partial \ln C/\partial \ln q_i$)			
q_1, Loans	0.80	0.68	1.20
q_2, Deposits	0.17	0.21	0.10
Overall ES ($\Sigma_i \; \partial \ln C/\partial \ln q_i$)	0.97	0.88	1.30

1/ Computed from column (2), appendix table. Branch-size cases selected on the basis of loan activity, 1982.

result is a U-shaped average cost curve, represented by the two branch-size cases reported in Table 2. The "small" branch would be a point on the downward-sloping portion of the average cost curve, whereas the "large" branch represents a point on the upward-sloping portion of the curve. The values of the partial scale economy measures reported in Table 1 indicate that there exist substantial economies of scale in the deposit mobilization activity of the bank. On the other hand, loan activity is approaching constant returns to scale for the average-branch size 6/ and displays diseconomies of scale in branches with large amounts of funds lent.

Effects of Loan Size and Deposit Size

The addition of both loan-size and deposit-size interactions to the cost system improved significantly the overall statistical performance of the estimation (see appendix table). However, only the individual coefficient of the loan-size (LS) variable was statistically significant, therefore these results should be used with caution. Both estimated coefficients, $\hat{\theta}_1$ and $\hat{\theta}_2$, show a negative sign meaning that the value of the scale economies measure decreases when the average size of loans and/or average size of deposits increase.

The effects of loan size and deposit size become more meaningful when the marginal costs of lending and the marginal costs of mobilizing deposits are considered. Equation (4) can be written in terms of the parameters of the cost function as follows:

$$MC_i = \frac{C}{q_i} (B_i + \gamma_{ii}\ln q_i + \gamma_{ik}\ln q_k + \theta_i \ln SZ) ,$$

where:

$$B_i = \alpha_i + \Sigma_j \eta_{ij}\ln p_j \quad , \qquad i = 1,2$$

SZ = LS (loan size) for i = 1, and SZ = DS (deposit size)

for i = 2. (10)

The signs of the estimates reported in the appendix table indicate that the marginal cost of lending is an increasing function of the total amount lent ($\hat{\gamma}_{11} > 0$), it is reduced by increases in total deposits mobilized ($\hat{\gamma}_{12} < 0$) and decreases as the average loan size increases ($\hat{\theta}_1 < 0$). Likewise, the marginal cost of mobilizing deposits is upward sloping with respect to the total value of deposits ($\hat{\gamma}_{22} > 0$), benefits from economies of joint production ($\hat{\gamma}_{12} < 0$) and shifts downward with increases in the average size of deposit balances ($\hat{\theta}_2 < 0$).

<u>Cost Complementarities and Elasticities of Factor Substitution and Factor Demand</u>

The estimates of the cost function parameters indicate that cost complementarities exist between loans and deposits. The evaluation of the necessary condition for cost complementarity (expression (5) in section 2) using the results in column 4 of the appendix table gives:

$$\hat{\gamma}_{12} + \hat{\alpha}_1\hat{\alpha}_2 = -0.4195,$$

therefore, the necessary condition (5) is satisfied by these results.

Table 2. Price Elasticities of Demand for Factors of Production, Derived from Cost Function Estimates[1/]

	Labor	Capital
Labor	-0.4310	0.4310
Capital	0.2123	-0.2123

1/ Based on cost system estimates, column (4) of appendix table.

The price elasticities of factor demand reported in Table 2, as well as the estimated value of the elasticity of substitution between capital and labor, $\hat{\sigma}_{12} = 0.64$, seem relatively low even though there are no appropriate points of reference in the literature revised.

5. Summary

This paper investigated and analyzed the cost-output relationships and production technology prevailing in the Agricultural Development Bank of Honduras. The main results reported above can be summarized as follows:

(a) The hypotheses of a simplified Cobb-Douglas-type function, with unitary elasticity of factor substitution is rejected by the statistical tests performed in this study. The use of a Cobb-Douglas cost function underestimates the cost increases due to increases in production.

(b) The estimates of scale economies obtained using the (preferred) GLS procedure on the translog cost-system differ from those obtained with single-equation (OLS) estimation. The scale-economies measure for the average branch is not significantly different from one.

(c) The measures of scale-economies obtained are a function of the output levels and of the output mix, in such a way that the overall average cost curves are U-shaped. There are important differences between the magnitudes of the partial economies of scale. While the returns to scale of lending activities approach unity, there are important unexploited economies of scale associated with the expansion of deposit mobilization.

(d) Cost complementarities between loans and deposits exist, therefore the marginal cost of lending will decrease with increases in the amount of deposits mobilized, and vice versa. As expected, increases in loan size and deposit size reduce the marginal costs of lending and mobilizing deposits respectively.

Notes

1/ See for example, Benston, Hanweck and Humphrey; Mullineaux; Murray and White; Panzar and Willig (1977). For a review of the pre-1970 literature, see Benston.

2/ For a more detailed characterization of the translog function see Binswanger; Christensen, Jorgenson, and Lau; Ray.

3/ Murray and White refer to this relationship as "economies of scope". However, Benston, Berger, Hanweck and Humphrey give a more strict definition for the concept of economies of scope. See also Panzar and Willig (1981).

4/ 1 Lempira = 0.5 dollar

5/ F-ratio obtained for the Cobb-Douglas hypothesis is 9.58.

6/ i.e., a hypothetical branch that can be represented by the sample means of all variables.

Appendix Table. Estimated Parameters of the Translog Cost Function, Single Equation <u>versus</u> System Estimation[1/]

Parameter (Variable)	(1) Single Equation (OLS) Estimate	t-ratio	(2) System of Equations (GLS) Estimate	t-ratio (asymptotic)	(3) Single Equation (OLS) Estimate	t-ratio	(4) System of Equations (GLS Estimate	t-ratio (asymptoti
α_0 (intercept)	5.3210	9.817*	4.3014	12.160*	5.1313	5.652*	6.1591	10.339*
α_1 ($\ln q_1$, loans)	0.1439	1.153	0.5109	6.836*	0.0574	0.297	0.6652	5.957*
α_2 ($\ln q_2$, deposits)	0.0163	0.101	0.1039	1.115	0.0768	0.212	-0.7631	-3.328*
β_1 ($\ln p_1$, labor)	0.5439	3.399*	0.3651	8.265*	0.7055	3.233*	0.5078	7.342*
β_2 ($\ln p_2$, capital)	0.4561	2.851*	0.6349	14.371*	0.2945	1.350	0.4922	7.118*
γ_{11} $(\ln q_1)^2$	0.0931	3.388*	0.1705	12.482*	0.0887	2.362°	0.1753	9.530*
γ_{22} $(\ln q_2)^2$	-0.0429	-1.211	0.0569	2.705*	0.0368	0.375	0.2646	4.343*
γ_{12} $(\ln q_1 \ln q_2)$	-0.0063	-0.257	-0.0665	-4.242*	0.0256	0.601	-0.0881	-3.419*
δ_{11} $(\ln p_1)^2$	0.0003	0.007	0.0973	10.784*	0.1191	1.257	0.0789	5.931*
δ_{22} $(\ln p_2)^2$	0.0003	0.007	0.0973	10.784*	0.1191	1.257	0.0789	5.931*
δ_{12} $(\ln p_1 \ln p_2)$	-0.0003	-0.007	-0.0973	-10.784*	-0.1191	-1.257	-0.0789	-5.931*
η_{11} $(\ln q_1 \ln p_1)$	-0.0426	-1.255	-0.1074	-14.269*	-0.0452	-1.007	-0.0947	-9.156*
η_{12} $(\ln q_1 \ln p_2)$	0.0426	1.255	0.1074	14.269*	0.0452	1.007	0.0947	9.156*
η_{21} $(\ln q_2 \ln p_1)$	0.0922	2.786*	0.0403	4.477*	-0.0284	-0.394	0.0189	1.255
η_{22} $(\ln q_2 \ln p_2)$	-0.0922	-2.786*	-0.0403	-4.477*	0.0284	0.394	-0.0189	-1.255
θ_1 $(\ln q_1 \ln LS)$	--	--	--	--	-0.0068	-1.059	-0.0105	-2.342°
θ_2 $(\ln q_2 \ln DS)$	--	--	--	--	-0.0143	-0.974	-0.0120	-1.132
R^2	0.8491	173.86[2/]	0.8598	119.59[2/]	0.8786	97.367[2/]	0.8828	67.31[2/]
Weighted R^2 (system)			0.6833[3/]				0.8043[4/]	

1/ Factor-price homogeneity restrictions imposed on all estimated functions. Cross-equation restrictions imposed on system estimation.

2/ F-ratio

3/ R^2 of labor-share equation : 0.2788, F-ratio = 27.35

4/ R^2 of labor-share equation : 0.2821, F-ratio = 15.23

* Significant at .01 level

° Significant at .05 level

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